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Title: Multidimensional Radiative Transfer Models of Kilonovae

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Multidimensional Radiative Transfer Models of Kilonovae

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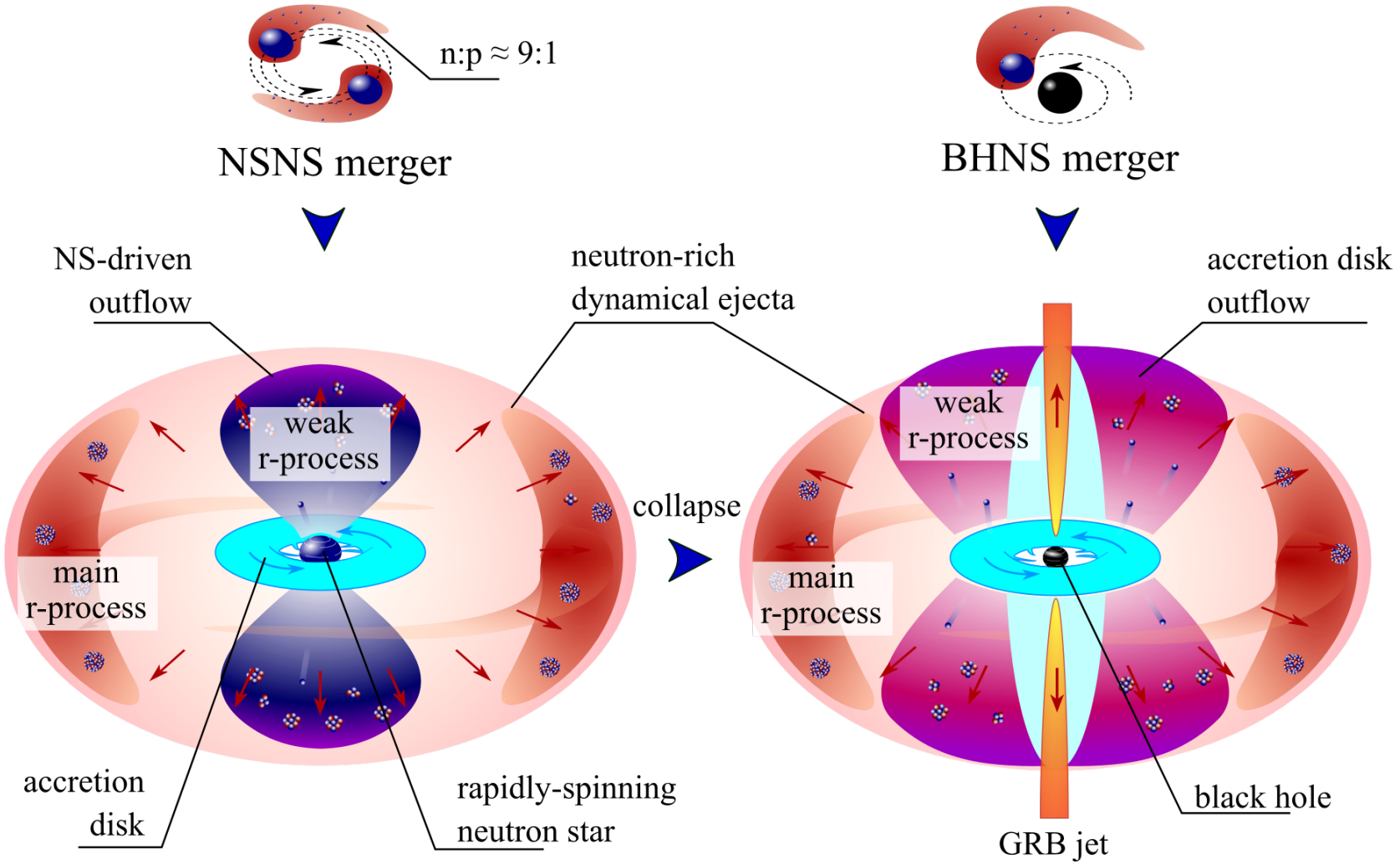
APS April Meeting

April 18th, 2021
LA-UR-XXXXX

Los Alamos NATIONAL LABORATORY EST. 1943

Neutron Star Mergers Scenario



SuperNu: Multidimensional MC Radiative Transfer Code

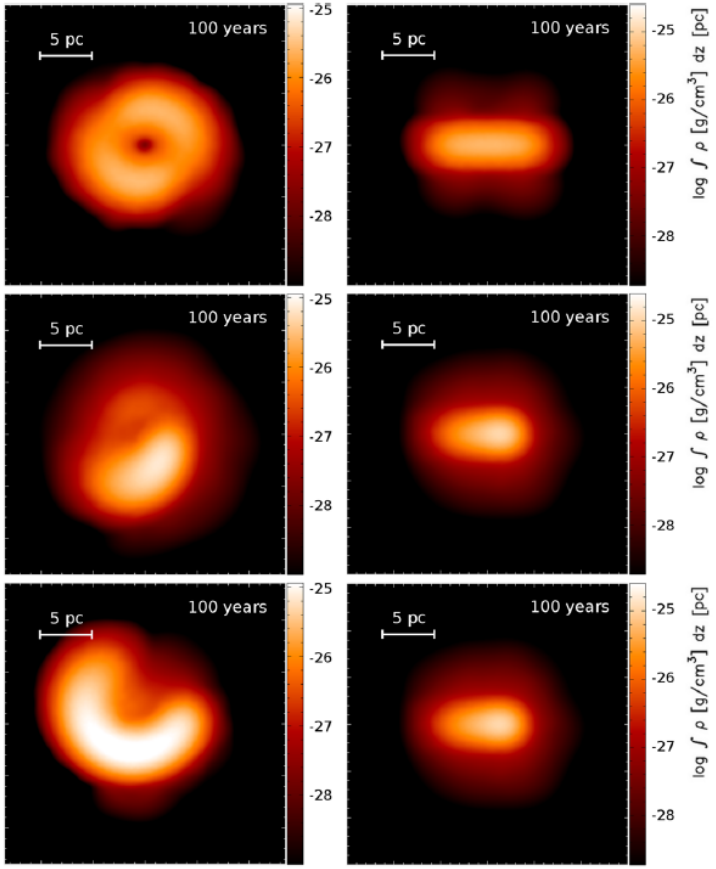
- written by Wollaeger and van Rossum, ApJS (2014);
- open source code, can be downloaded at: https://bitbucket.org/drrossum/supernu
- multidimensional (1D spherical, 2D axisymmetry, 3D);
- combines Implicit Monte Carlo (IMC) + Discrete Diffusion Monte Carlo (DDMC);
- background flow: partially-ionized multicomponent plasma;
- expansion: homologous approximation, $v = r / t$;
- first-order relativistic corrections (up to $O(v/c)$);
- opacity: >1000 log-spaced wavelength groups in comoving frame, (from 10 nm to 12.8 μm in our simulations);

Astrophysical problems we are trying to address:

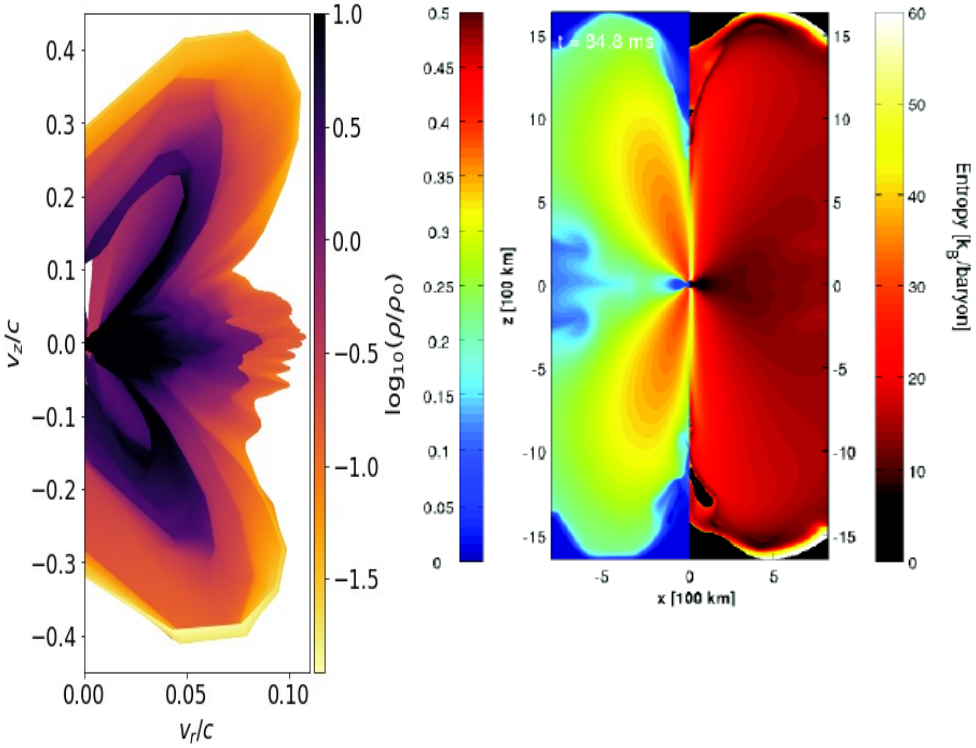
- What *can* and *can not* be inferred about ejecta geometry from kilonova spectra and light curves?
- How big are the *uncertainties* in the deduced quantities?
- What is the *composition* of the kilonova ejecta?
- *Kilonova tomography*: how to reconstruct the shape of ejecta from light curves and spectra?
- Deciphering multimessenger signal of *GW170817*
- *The origin of the r-process in the Universe*
- *What is the true high-density equation of state?*

Non-spherical, multicomponent character of ejecta

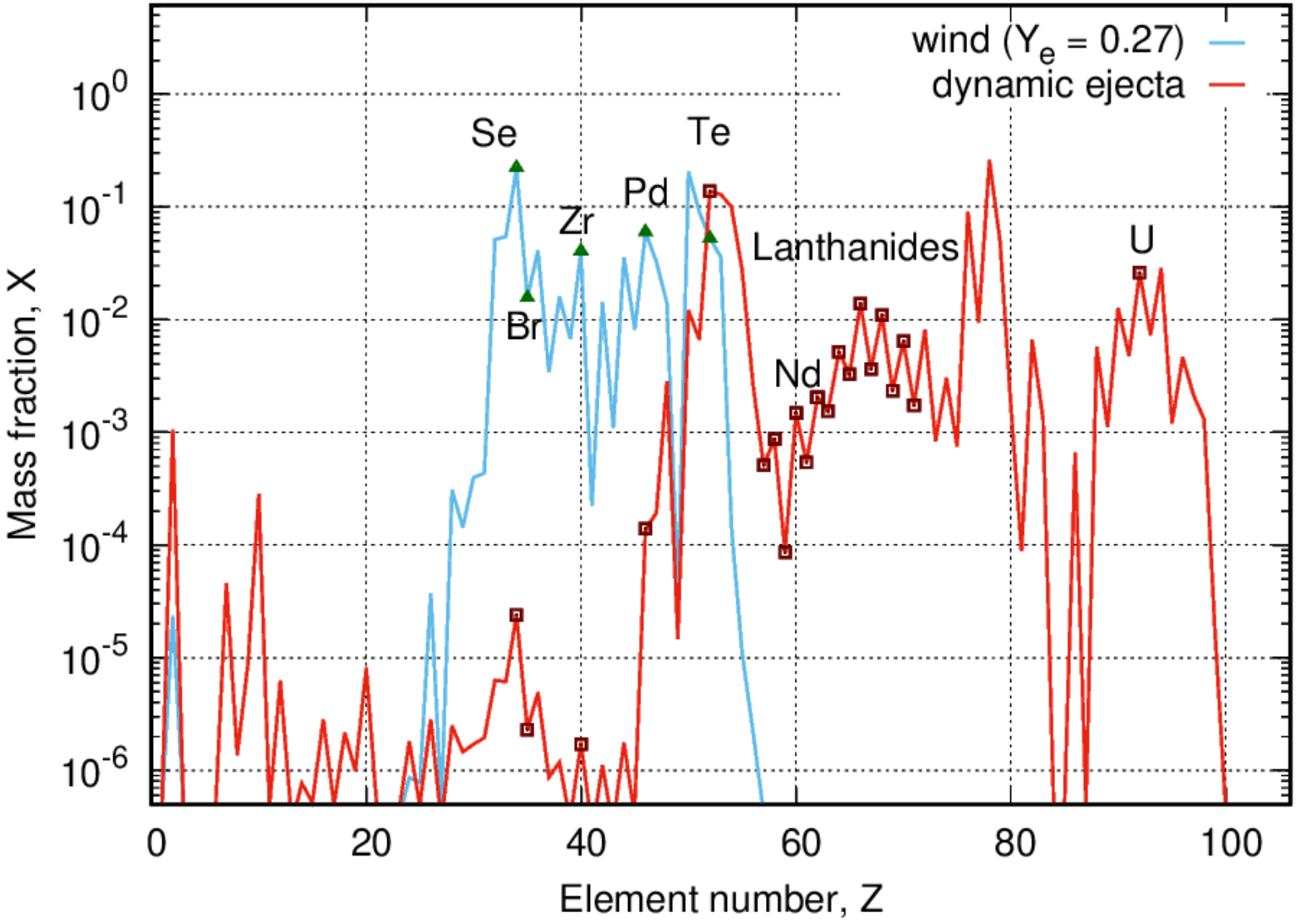
Dynamical ejecta (Rosswog, OK +2014)



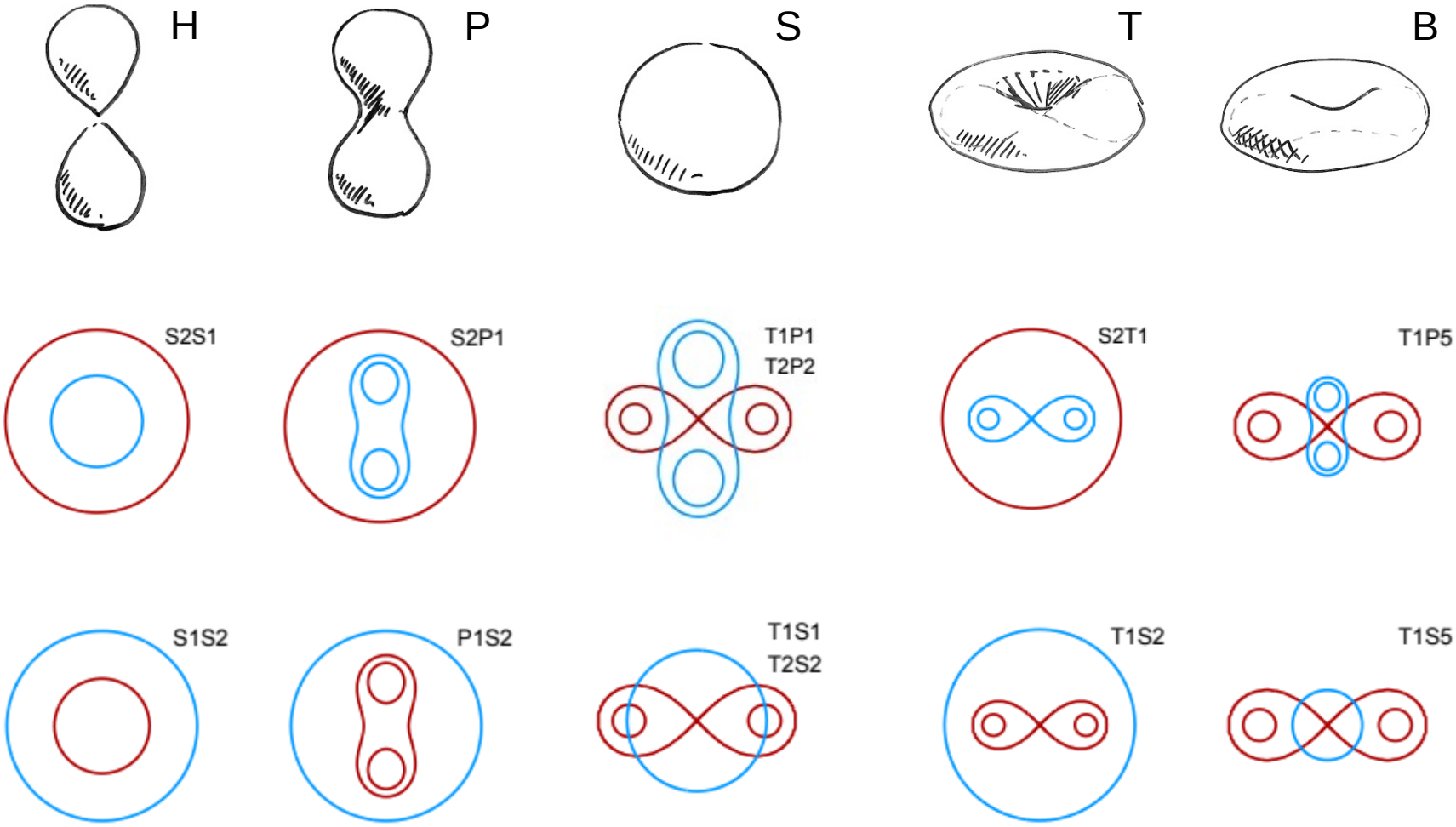
Wind (Miller+2019) (Perego+2014)



Selecting representative compositions

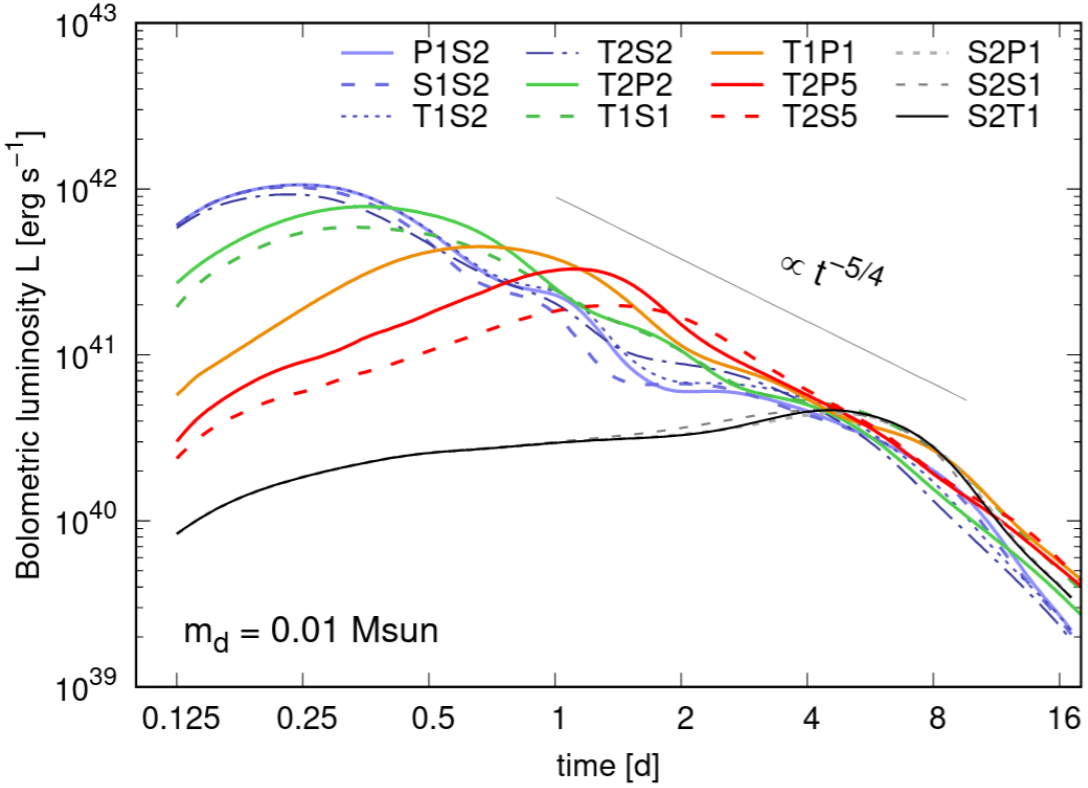


Two-component axisymmetric models



arXiv:2004.00102

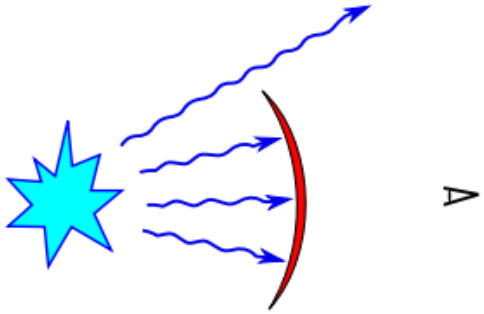
Morphological variability in bolometric light curves



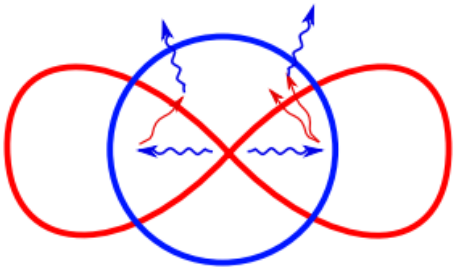
arXiv:2004.00102

- With detailed, temperature-dependent opacities the morphology affects the light curves more than the mass and velocity of the ejecta.
- Without strong constraints on the geometry, artificially large or small masses can be inferred from non-spherical explosions.

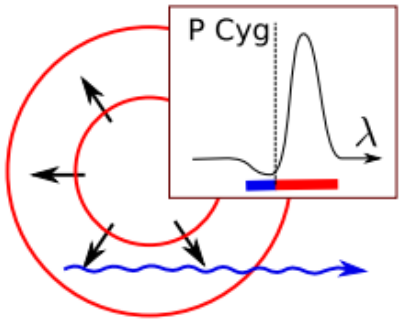
Multidimensional effects in radiative transfer models:



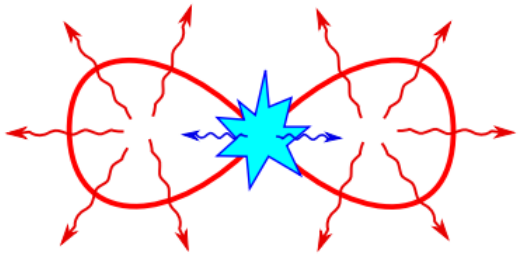
1. Lanthanide curtain



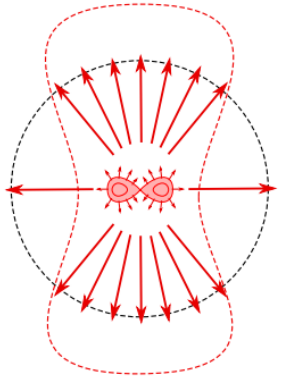
3. Double reprocessing



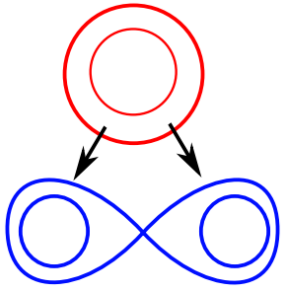
5. P Cygni features



2. Flux reprocessing



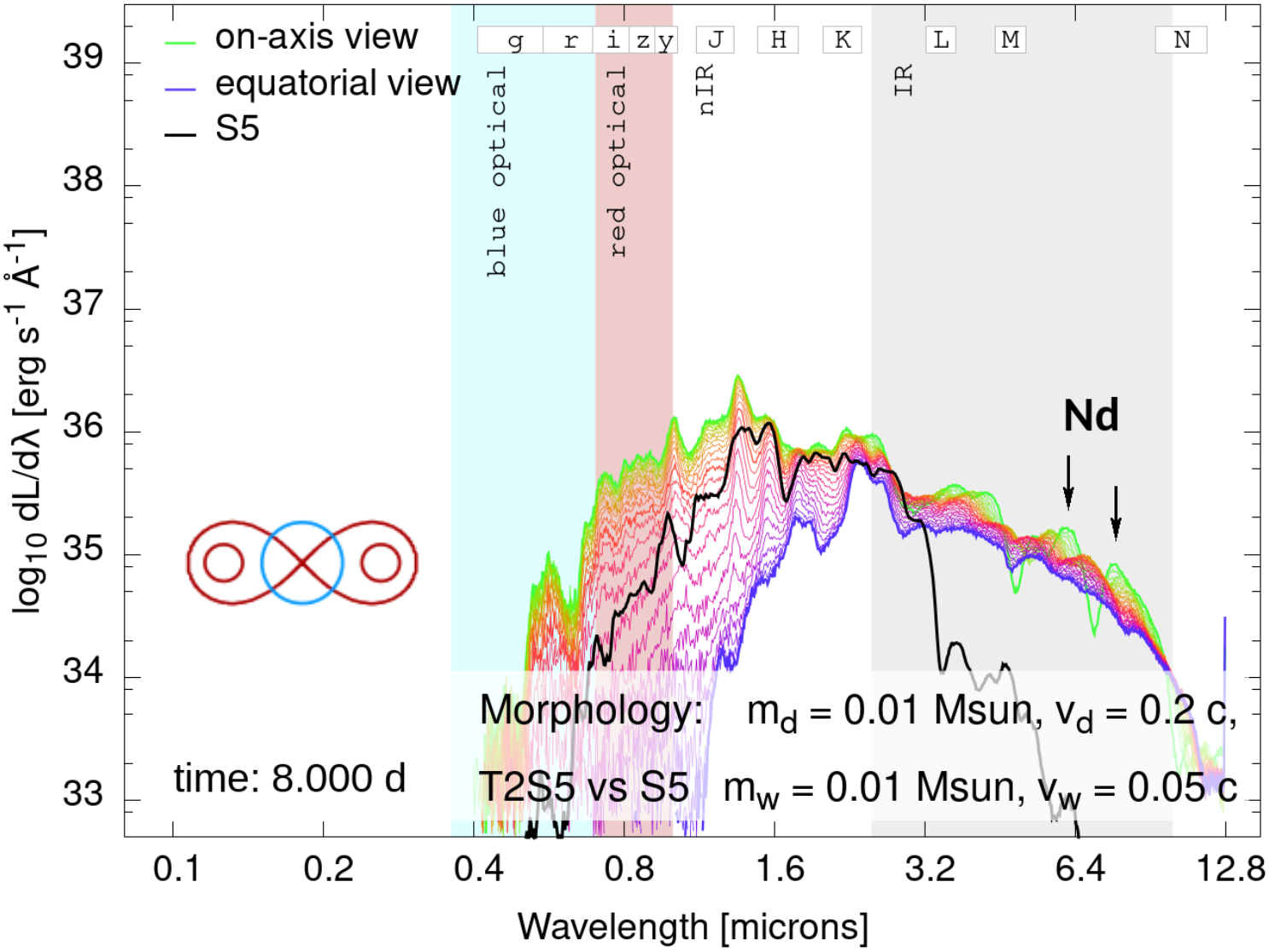
4. Projected area of the photosphere, flux redirection



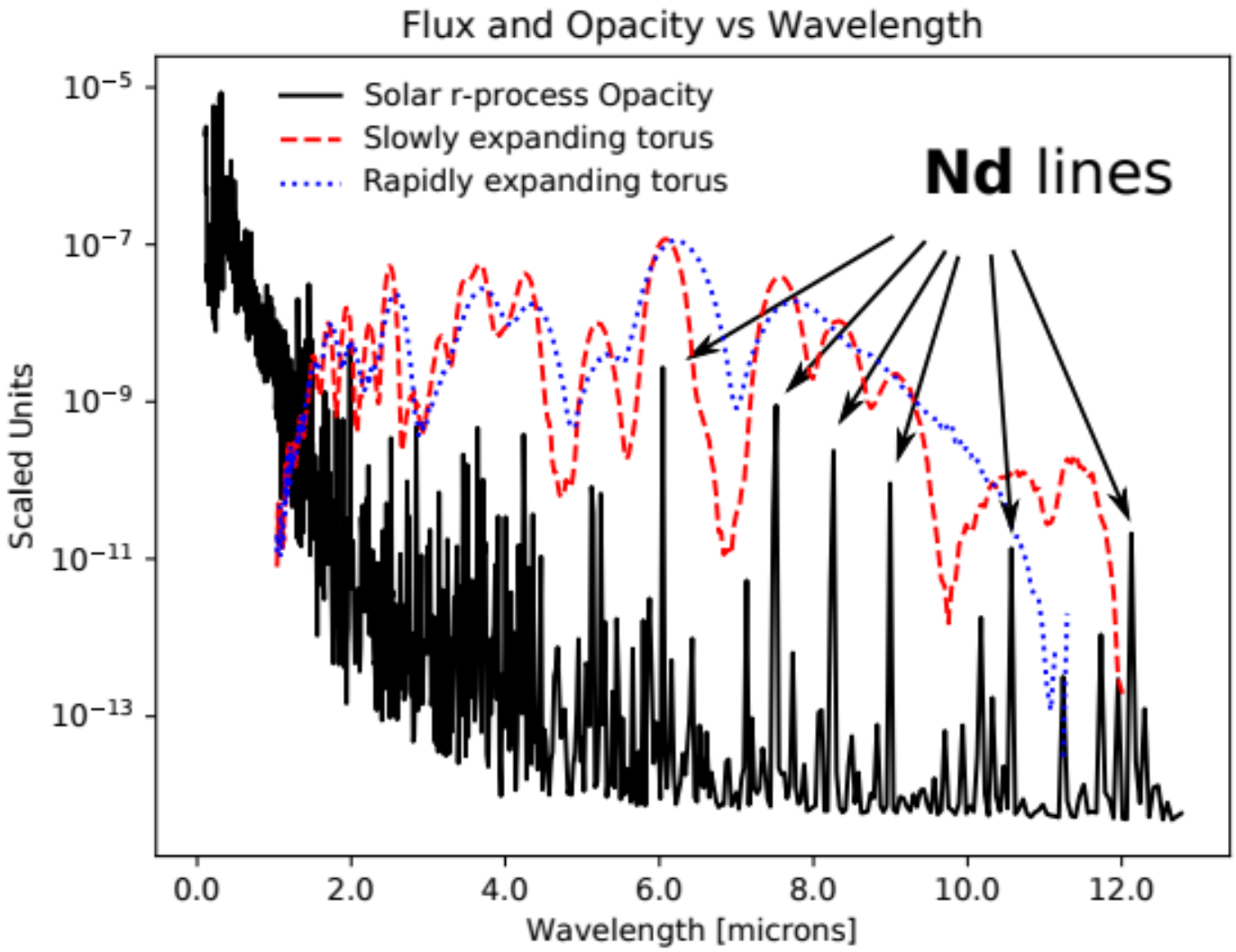
6. Heat retention

arXiv:2004.00102

“Lanthanide curtain” and double reprocessing effects



P Cygni features at late time



Conclusions and Results

Conclusions:

- Without strong constraints on the geometry, artificially large or small masses can be inferred from non-spherical explosions.
- Heat retention in models with local density enhancements produces longer-lasting, bluer kilonovae.
- Even a small mass (0.001Msun) of lanthanide-rich component is enough to fully block the optical emission of a blue KN.
- At late epochs (about 8 days), models with rapidly expanding lanthanide-rich ejecta exhibit pronounced P Cygni features, allowing the characterization of composition and line-of-sight velocity of the ejecta.
- Double reprocessing and flux focusing by toroidal component can increase kilonova brightness in addition to projected-area effect.